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(54) **METHOD FOR DETECTION OF FLUID FLOW**

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B05B 12/00 (2018.01)

(52) **U.S. Cl.**
CPC ***B05B 12/087*** (2013.01); ***B05B 12/006*** (2013.01)

(58) **Field of Classification Search**
CPC B05B 12/006; B05B 12/008; B05B 12/085–088; G01L 19/0007; G01L 19/0061
See application file for complete search history.

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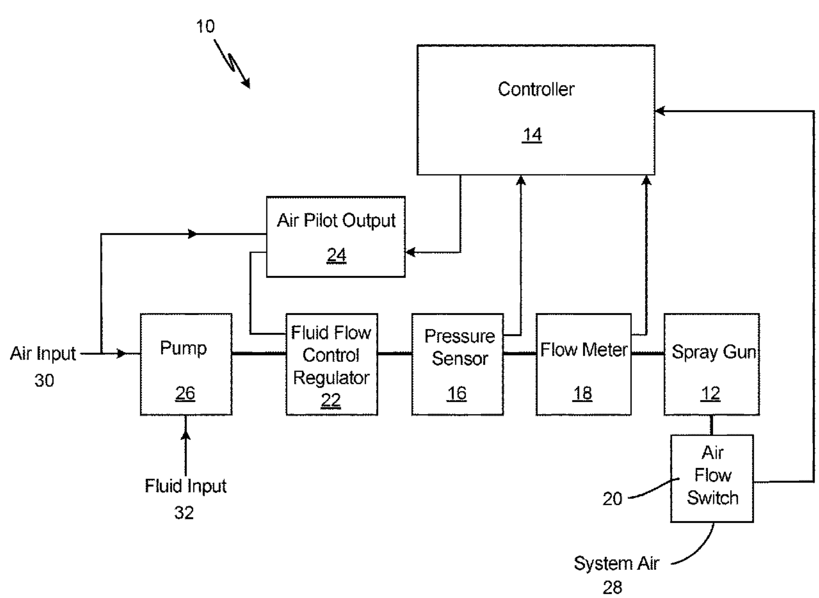
(57) **ABSTRACT**

A spray gun system includes a spray gun, a pressure sensor, and a controller. The spray gun is configured to distribute a mixture of air and fluid onto a working surface. The pressure sensor is fluidly connected to the spray gun and is configured to measure fluid pressure within the spray gun system. The controller is electrically connected to the pressure sensor and is configured to calculate pressure error based on the measured pressure and a pressure set-point. The controller is further configured to increment a counter if the pressure error exceeds an error threshold, perform a flow control to adjust the pressure set-point to achieve a target flow rate in response to determining that the increment counter exceeds a count threshold, and perform a pressure control loop to adjust the fluid pressure within the spray gun system to achieve the pressure set-point.

12 Claims, 4 Drawing Sheets



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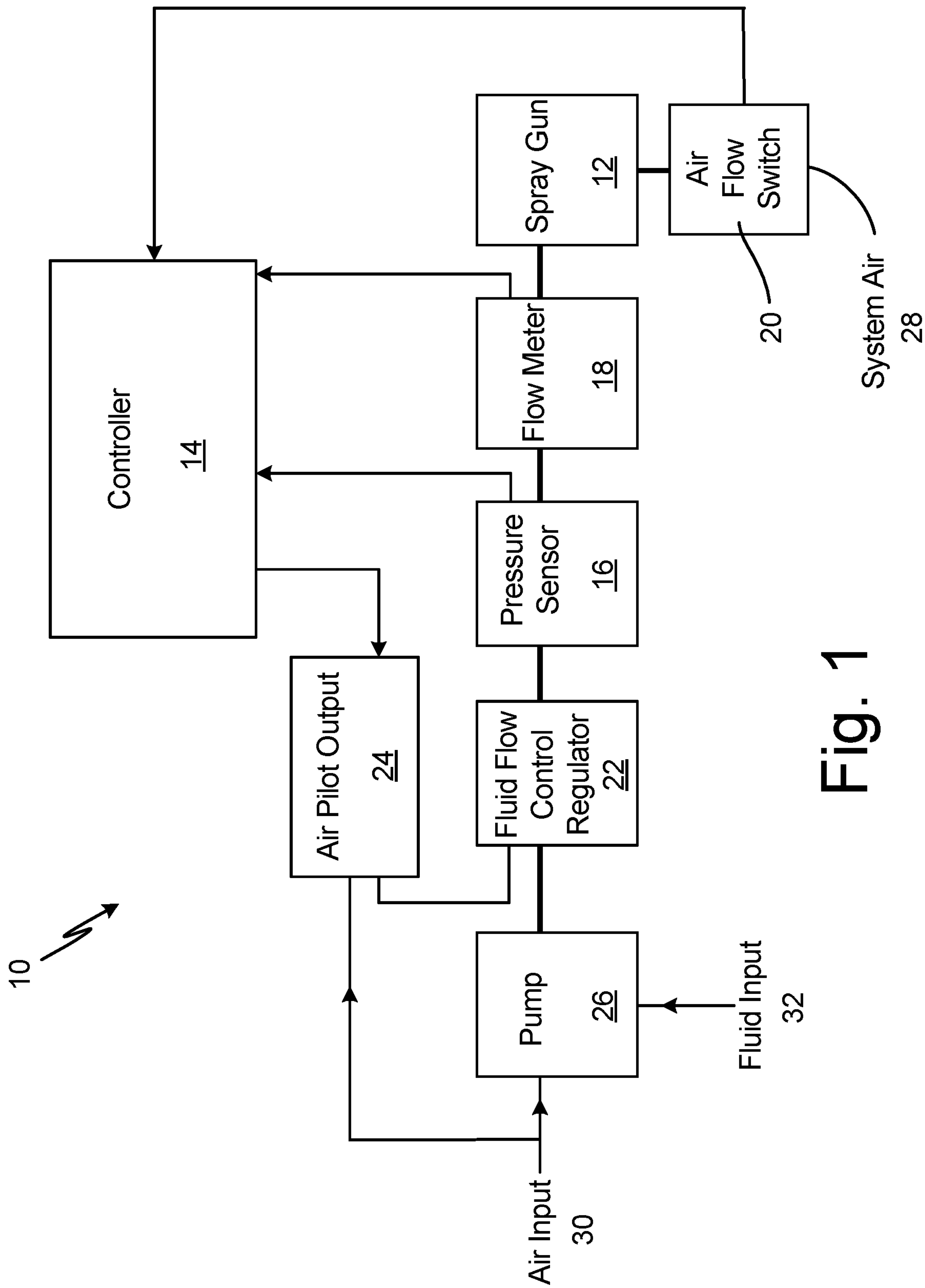
Spray Gun
12
Air
Flow
Switch
Controller
14
Flow Meter
18
20
System Air
28
Pressure
Sensor
16
Air Pilot Output
24
Fluid Flow
Control
Regulator
22
10
Pump
26
Fluid Input
32
Air Input
30

Fig. 1

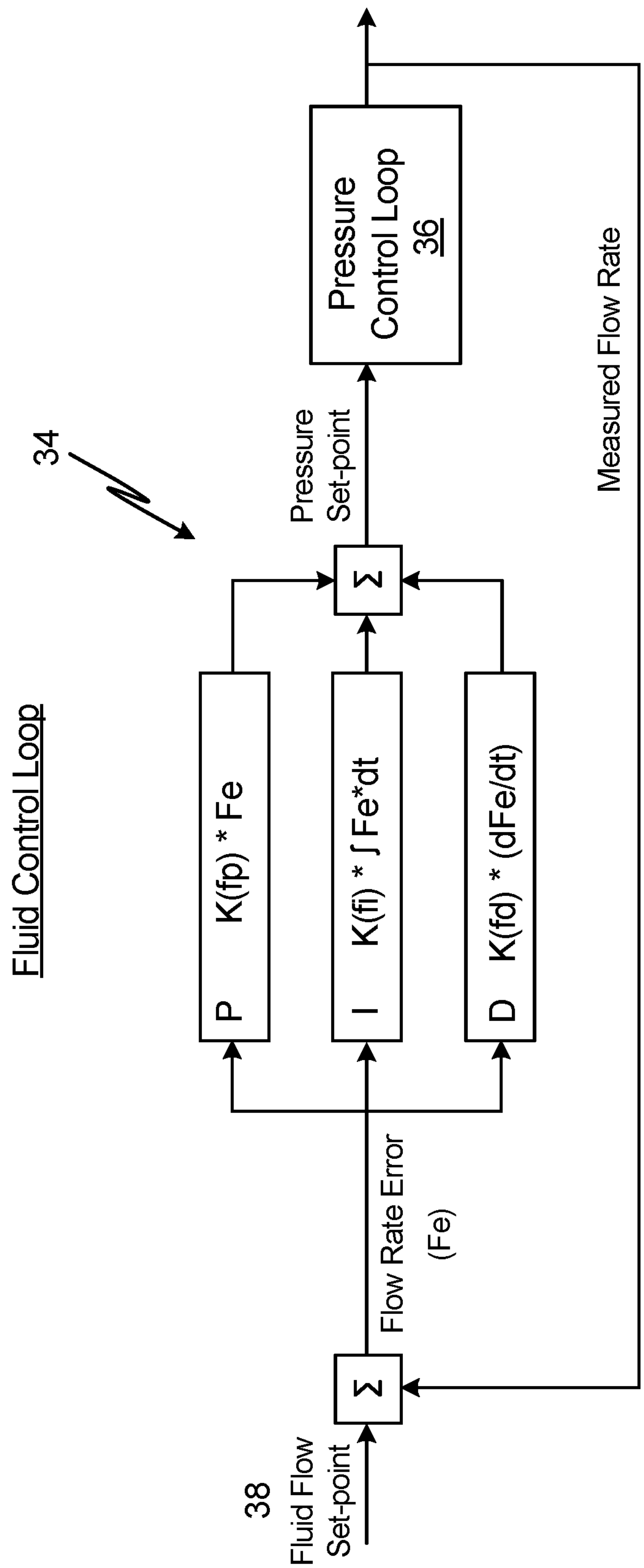
Fluid Control Loop
34
P K(fp) * Fe
I K(fi) * ∫ Fe*dt
D K(fd) * (dFe/dt)
Σ
Σ
Pressure Set-point
Pressure Control Loop 36
Measured Flow Rate
Flow Rate Error (Fe)
38
Fluid Flow Set-point

Fig. 2A

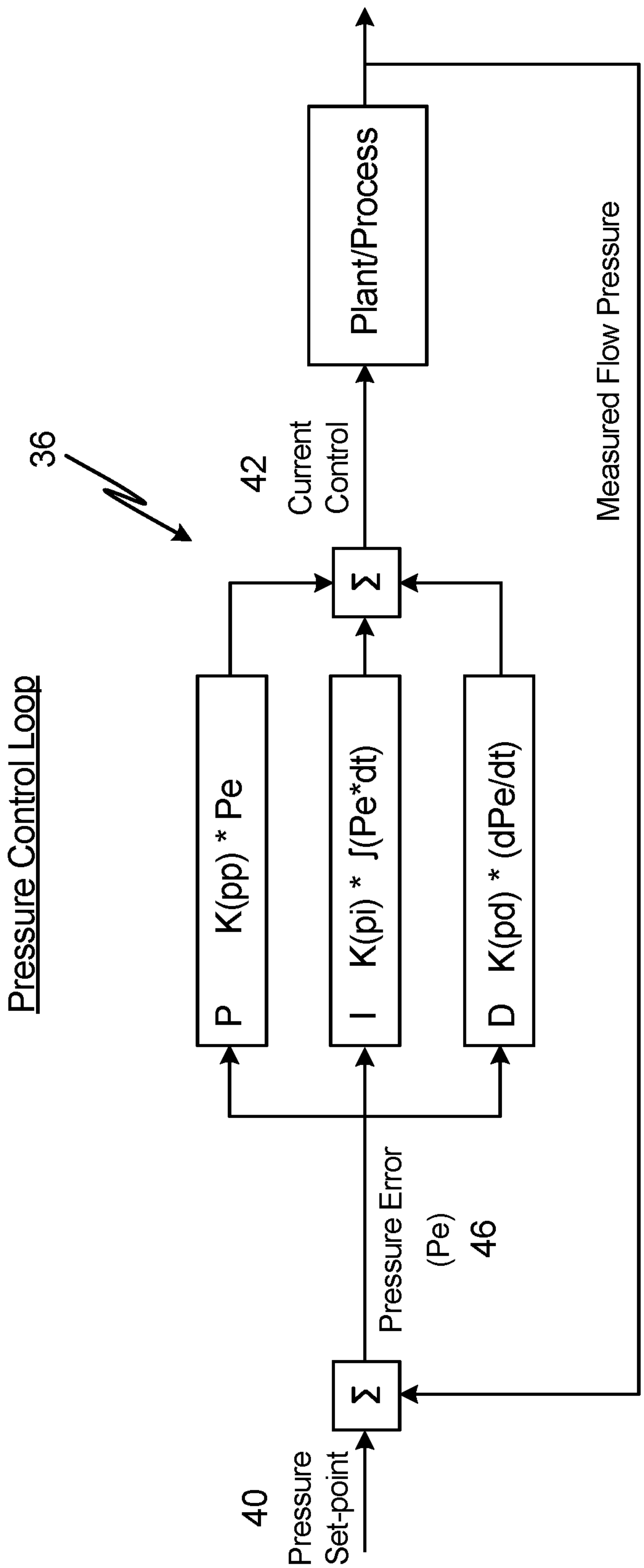
Pressure Control Loop
36
40
Pressure
Set-point
Σ
Pressure Error
(Pe)
46
P K(pp) * Pe
I K(pi) * ∫(Pe*dt)
D K(pd) * (dPe/dt)
Σ
42
Current
Control
Plant/Process
Measured Flow Pressure

Fig. 2B

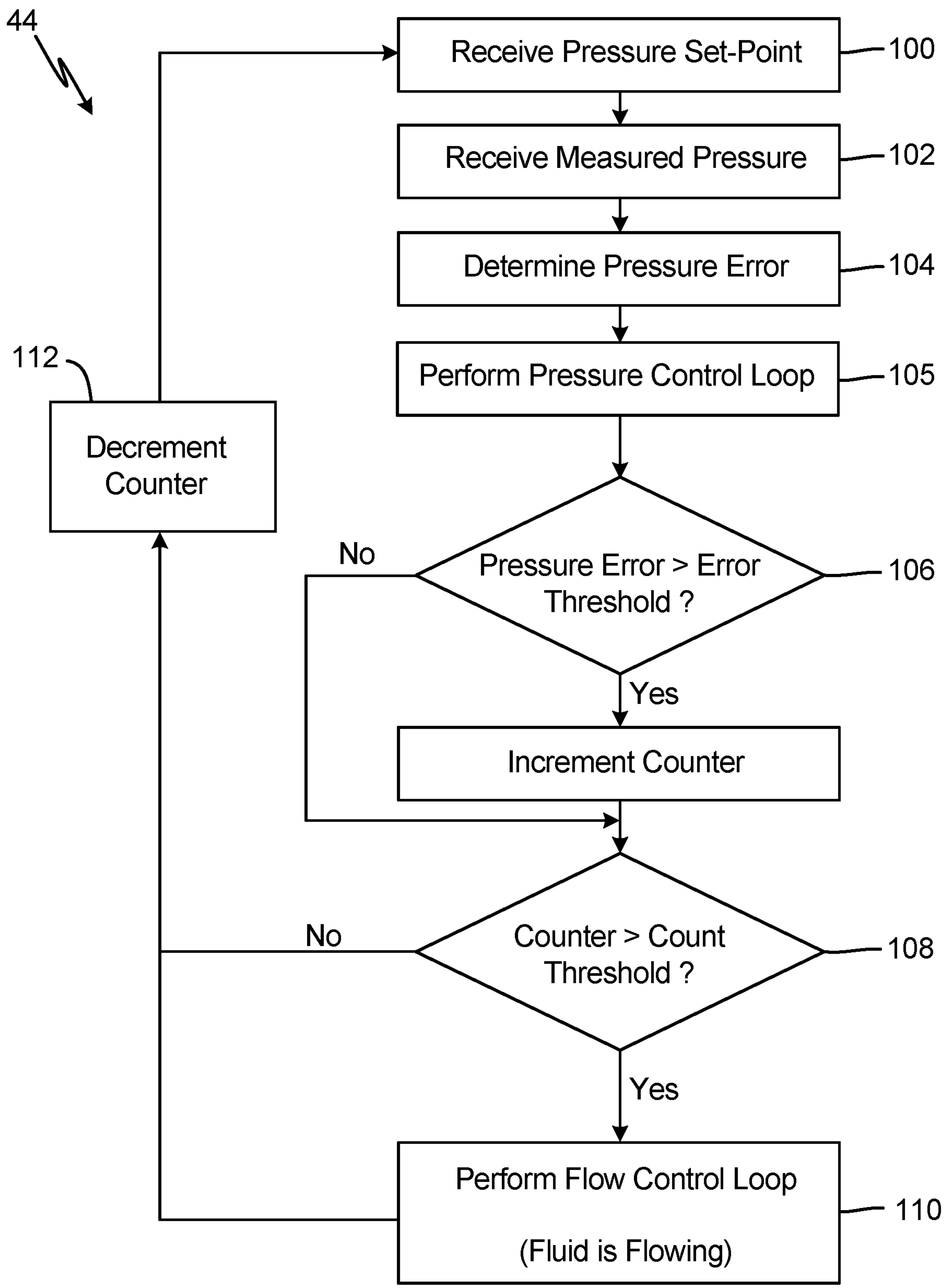
44
Receive Pressure Set-Point
100
Receive Measured Pressure
102
Determine Pressure Error
104
Perform Pressure Control Loop
105
112
Decrement Counter
No
Pressure Error > Error Threshold ?
106
Yes
Increment Counter
No
Counter > Count Threshold ?
108
Yes
Perform Flow Control Loop
(Fluid is Flowing)
110

Fig. 3

METHOD FOR DETECTION OF FLUID FLOW

BACKGROUND

The present disclosure relates to a spray gun system, and more particularly, to a method for detecting fluid flow in a spray gun system.

Spray guns are used to spray liquids, such as paint, under pressure onto a working surface. Spray guns can be used for many different applications but in many applications the spray gun is either pressure controlled or flow controlled to achieve the desired flow rate output. In a pressure controlled system, the user controls the dispensing flow rate by adjusting the pressure of the pump system, nozzle size, and the gun trigger opening position. In addition, a controller connected to both an electronically-controlled proportional valve and an electronic fluid pressure sensor attempts to drive the system pressure to the target pressure using closed-loop feedback control.

In a flow controlled system, the user controls the dispensing flow rate by setting the target flow rate in the controller. The controller is connected to and receives data from an electronically-controlled proportional valve, an electronic fluid pressure sensor, and an electronic flow meter. The controller uses feedback control techniques to adjust parameters of the spray gun system in an attempt to achieve the user-defined target fluid flow rate. In some flow controlled applications, the system can become over-pressured if only air and no fluid is dispensing from the spray gun. If only air is flowing from the spray gun, the controller may attempt to increase pressure rapidly because the flow meter is not returning a measurement equal to the target flow rate. If this occurs, the system may quickly become over-pressured, resulting in too much flow rapidly exiting the spray gun and an unsatisfactory finish on the working surface.

SUMMARY

According to one aspect of the disclosure, a spray gun system includes a spray gun, a pressure sensor, and a controller. The spray gun is configured to distribute a mixture of air and fluid onto a working surface. The pressure sensor is fluidly connected to the spray gun and configured to measure the fluid pressure within the spray gun system. The controller is electrically connected to the pressure sensor and configured to: receive a measured pressure from the pressure sensor; calculate pressure error based on the measured pressure and a pressure set-point; compare the pressure error to an error threshold; increment a counter if the pressure error exceeds the error threshold; perform, in response to determining that the increment counter exceeds a count threshold, a flow control loop that adjusts the pressure set-point to achieve a target flow rate; and perform a pressure control loop to adjust the fluid pressure within the spray gun system to achieve the pressure set-point.

According to another aspect of the disclosure, a method for detecting fluid flow in a spray gun system includes receiving, by the controller, a pressure measurement from the pressure sensor that is fluidly connected to the spray gun and electrically connected to the controller. The method further includes calculating, by the controller, the pressure error based on the measured pressure and a pressure set-point, comparing, by the controller, the pressure error to an error threshold, and incrementing, by the controller, a counter if the pressure error exceeds the error threshold. The method further includes performing, by the controller, in response to determining that the increment counter exceeds a count threshold, a flow control loop that adjusts the pressure set-point to achieve a target flow rate, and performing, by the controller, a pressure control loop to adjust the fluid pressure within the spray gun system to achieve the pressure set-point.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram of a spray gun system.

FIG. **2**A is a schematic block diagram of an example fluid control loop within the spray gun system.

FIG. **2**B is a schematic block diagram of an example pressure control loop within the spray gun system.

FIG. **3** is a flowchart illustrating example operations of the fluid flow detection process within the spray gun system.

DETAILED DESCRIPTION

FIG. **1** is a schematic block diagram of spray gun system **10** which includes spray gun **12**, controller **14**, pressure sensor **16**, flow meter **18**, airflow switch **20**, fluid flow control regulator **22**, air pilot output **24**, and pump **26**.

Spray gun **12** can be a manual, hand-held spray gun in which a user operates a trigger to discharge a liquid (e.g. paint) from a nozzle onto a working surface. Controller **14** can be a controller device configured to be communicatively coupled with components of spray gun system **10** for monitoring and control of the components during operation of the spray gun system **10**, as is discussed further below. Pressure sensor **16** can be a device, such as a pressure transducer or other device, for measuring the pressure of gases or liquids that generates and sends a signal as a function of the pressure imposed on the device. Flow meter **18** can be a device capable of calculating the flow of a fluid by determining the forces produced by the flowing fluid as it overcomes a known constriction.

Airflow switch **20** can be a device that detects gas flow in a system and sends a signal indicating detection of the gas flow. Fluid flow control regulator **22** can be a device that regulates the flow or pressure (e.g. by adjusting the size of an orifice) of a fluid flowing through spray gun system **10**. Air pilot output **24** can be a device that increases and/or decreases air pressure within spray gun system **10** to increase and/or decrease fluid pressure within fluid flow control regulator **22**. Pump **26** can be a device that moves fluids using mechanical action. For example, pump **26** can be an electrically powered pump, a pneumatically powered pump, an engine powered pump, or any other type of pump capable of moving a fluid in spray gun system **10**.

Though not shown in FIG. **1** for purposes of clarity and ease of illustration, controller **14** includes one or more processors and computer-readable memory. Examples of the one or more processors can include any one or more of a microprocessor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or other equivalent discrete or integrated logic circuitry.

Computer-readable memory of controller **14** can be configured to store information within controller **14** during operation. The computer-readable memory can be described, in some examples, as computer-readable storage media. In some examples, a computer-readable storage medium can include a non-transitory medium. The term "non-transitory" can indicate that the storage medium is not embodied in a carrier wave or a propagated signal. In certain examples, a non-transitory storage medium can store data that can, over time, change (e.g., in RAM or cache). Computer-readable memory of controller **14** can include volatile and non-volatile memories. Examples of volatile memories can include random access memories (RAM), dynamic random access memories (DRAM), static random access memories (SRAM), and other forms of volatile memories. Examples of non-volatile memories can include magnetic hard discs, optical discs, flash memories, or forms of electrically programmable memories (EPROM) or electrically erasable and programmable (EEPROM) memories.

Controller **14** can be a controller device configured to be communicatively coupled with components of spray gun system **10**, such as pressure sensor **16**, flow meter **18**, airflow switch **20**, and air pilot output **24**, for monitoring and control of the components during operation of the spray gun system **10**. In some examples, controller **14** includes and/or is operatively coupled to a display device and/or user interface elements (e.g., buttons, dials, graphical control elements presented at a touch-sensitive display, or other user interface elements) to enable user interaction with controller **14**, such as for initialization, monitoring, and/or control of the system. Though not illustrated in the example of FIG. **1**, in certain examples, controller **14** can be communicatively coupled to one or more remote computing devices, such as via a wired or wireless communications network, or both.

Spray gun **12** is pneumatically connected to and receives a gas flow, such as air, through airflow switch **20**. Airflow switch **20** receives system air **28** through a hose or tube connected to airflow switch **20**. Airflow switch **20** is also electrically connected to controller **14**. Airflow switch **20** is configured to send airflow data to controller **14**, indicating when air has begun to flow within spray gun system **10**.

Spray gun **12** is also fluidly connected to and receives fluid flow through flow meter **18**. Flow meter **18** is fluidly connected to both spray gun **12** and pressure sensor **16** and receives fluid flow through pressure sensor **16**. Flow meter **18** is also electrically connected to controller **14** and flow meter **18** is configured to send fluid flow rate measurements to controller **14**. In the embodiment shown, flow meter **18** is positioned between spray gun **12** and pressure sensor **16**. In another embodiment, flow meter **18** can be positioned upstream of pressure sensor **16** or fluid flow control regulator **22**. For example, flow meter **18** could be positioned between pressure sensor **16** and fluid flow control regulator **22**. In another example, flow meter **18** could be positioned between fluid flow control regulator **22** and pump **26**.

Pressure sensor **16** is fluidly connected to both flow meter **18** and fluid flow control regulator **22**. Pressure sensor **16** receives fluid flow through fluid flow control regulator **22**. Pressure sensor **16** is also electrically connected to controller **14** and pressure sensor **16** is configured to send fluid pressure measurements to controller **14**. Fluid flow control regulator **22** is fluidly connected to both pressure sensor **16** and pump **26**. Fluid flow control regulator **22** receives fluid flow through pump **26**. Fluid flow control regulator **22** is also pneumatically connected to air pilot output **24** and fluid flow control regulator **22** receives pressurized input air from air pilot output **24**. Air pilot output **24** is pneumatically connected to both fluid flow control regulator **22** and air input **30**. Air pilot output **24** receives pressurized air from air input **30** and supplies the pressurized air to fluid flow control regulator **22**.

Air pilot output **24** is also electrically connected to controller **14** and controlled by signals received from controller **14**, such as a current, voltage, or other control signal configured to cause air pilot output **24** to increase and/or decrease air pressure provided to fluid flow control regulator **22** via air pilot output **24**. Pump **26** is fluidly connected to fluid flow control regulator **22**. Pump **26** receives working fluid (e.g., paint) from fluid input **32**. Pump **26** is also pneumatically connected to air input **30** which supplies a gas, such as air, to power pump **26**.

In operation, working fluid enters pump **26** through fluid input **32** and air enters pump **26** through air input **30**. The air entering pump **26** is used to power pump **26** and allows pump **26** to drive fluid through spray gun system **10** under pressure. Pressurized air from air input **30** is also directed to air pilot output **24**. Air pilot output **24** uses the pressurized air to control the fluid pressure within fluid flow control regulator **22** based on a command received from controller **14** to adjust pressure within spray gun system **10**, such as a current, a voltage, or other control signal.

Fluid flow control regulator **22** receives fluid from pump **26** and is configured to control the fluid pressure within spray gun system **10** by, e.g., adjusting the size of an orifice within fluid flow control regulator **22** or otherwise increasing and/or decreasing pressure of the fluid according to the control signal received from air pilot output **24**. The pressurized fluid exiting fluid flow control regulator **22** is driven through spray gun system **10**. Pressurized fluid driven through fluid flow control regulator **22** is received by pressure sensor **16**, which is configured to measure the fluid pressure within spray gun system **10** and transmit the fluid pressure measurement to controller **14** for further processing, as is discussed further below.

In the embodiment shown, flow meter **18** receives fluid from pressure sensor **16** and is configured to measure the fluid flow rate of spray gun system **10** and transmit the flow rate measurement to controller **14** for further processing, as is discussed further below. The pressurized fluid reaches spray gun **12** where it is mixed with a flow of air in response to operator action to activate spray gun **12**, such as via a trigger or other actuation mechanism of spray gun **12**. The flow of air passes airflow switch **20**, causing airflow switch **20** to send a signal to controller **14** indicating that air is flowing within spray gun system **10**. The mixture of pressurized fluid and pressurized air atomizes the fluid mixture, resulting in a satisfactory finish on the working product.

According to techniques of this disclosure, controller **14** implements closed-loop control operations to control fluid pressure within spray gun system **10** to achieve a target flow rate of fluid distributed from spray gun **12**, such as a user-defined target flow rate (e.g., entered via a user interface of controller **14**), a system-defined target flow rate, a predefined target flow rate, or other target flow rate. For instance, as is further described below, controller **14** can implement a flow control loop that adjusts a pressure set-point to achieve the target flow rate. The flow control loop can be implemented as a proportional-integral-derivative (PID) control loop or other closed-loop control algorithm. For example, controller **14** can receive, as feedback, a measured flow rate of fluid within spray gun system **10** from flow meter **18**, the measured flow rate indicating a rate of fluid flowing through spray gun system **10** from pump **26** to spray gun **12**. Controller **14** can increase and/or decrease the pressure set-point in a controlled manner (i.e., via the flow control feedback loop) to achieve the target flow rate.

Controller **14** can further implement a pressure control loop (e.g., a PID control loop or other closed-loop control algorithm) to adjust fluid pressure within spray gun system **10** to achieve the pressure set-point defined by the flow control loop. For instance, controller **14** can receive, as feedback, a measured pressure of fluid within spray gun system **10** via pressure sensor **16**. Controller **14** can output, via the pressure control loop, a control command (e.g., a voltage, a current, or other control command) to air pilot output **24** to cause air pilot output **24** to increase and/or decrease the fluid pressure via fluid flow control regulator **22**.

As such, controller **14** can control a pressure set-point via a flow control loop (e.g., an outer loop) to achieve a target flow rate, such as a user-defined target flow rate configured to produce a satisfactory finish of the fluid (e.g., paint) on a working product. Controller **14** can further control fluid pressure within spray gun system **10** via a pressure control loop (e.g., an inner loop) to achieve the pressure set-point determined via the flow control loop.

In some examples, spray gun **12** can be manually actuated (e.g., via a trigger or other actuation mechanism) such that only pressurized air flows through spray gun **12**. That is, in certain examples, spray gun **12** can be manually actuated via user input to a trigger or other mechanism so that pressurized air is distributed from spray gun **12** and fluid (e.g., paint) is not distributed from spray gun **12**, such as for the often-termed "dusting" of the surface of the working product. In such examples, air flowing through spray gun **12** is sensed by airflow switch **20**, which transmits a signal (e.g., an electrical signal) to controller **14** indicating that air is being distributed by spray gun **12**. Since fluid is not being distributed by spray gun **12** in such examples, fluid pressure within spray gun system **10** is maintained at the pressure set-point via the pressure control loop implemented by controller **14**. However, in examples where fluid is not being distributed, the error term in the flow control loop representing a difference between the target flow rate and the measured flow rate can be large, thereby resulting in an increased pressure set-point and a buildup of fluid pressure within spray gun system **10** via operation of the pressure control loop to achieve the increased pressure set-point.

As such, according to techniques described herein, controller **14** executes the flow control loop to achieve the target flow rate in response to determining that fluid is being distributed from spray gun **12**. Controller **14** refrains from executing the flow control loop to achieve the target flow rate in response to determining that fluid is not being distributed from spray gun **12**, but rather executes only the pressure control loop to maintain the pressure set-point. As such, controller **14** can maintain the pressure set-point when fluid is not being distributed without resulting in a buildup of system pressure and the undesirable spraying effects resulting therefrom.

Moreover, controller **14** can determine whether fluid is being distributed from spray gun **12** based on an error term within the pressure control loop representing a difference between the pressure set-point and the measured pressure received from pressure sensor **16**. That is, rather than utilize the flow rate measurement from flow meter **18**, which can introduce latency into the flow detection operations, controller **14** can determine whether fluid is flowing within spray gun system **10** using the pressure error term within the pressure control loop. Such flow detection operations can identify, based on the tendency of pressure to decrease within moving fluid, the movement of fluid within spray gun system **10** prior to detection by flow meter **18**. As such, controller **14**, monitoring the pressure error term within the pressure control loop, can quickly and reliably identify the movement of fluid within spray gun system **10**, thereby enabling controller **14** to quickly and efficiently respond to moving fluid to execute the flow control loop and provide satisfactory finish to the working product.

FIG. **2**A is a schematic block diagram of fluid control loop **34**, which is executed by controller **14** of spray gun system **10**. FIG. **2**B is a schematic block diagram of pressure control loop **36**, which is executed by controller **14** of spray gun system **10**. FIGS. **2**A and **2**B will be discussed together. FIGS. **2**A and **2**B both include a proportional-integral-derivative (PID) control loop, with FIG. **2**A showing a fluid flow PID control loop and FIG. **2**B showing a pressure PID control loop. PID control loops continuously calculate an error value, which is the difference between a desired set-point and a measured process variable, and then apply a correction based on proportional, integral, and derivative terms of the error. PID control loops can be used to automatically apply accurate and responsive correction to a control function with minimal delay and overshoot, resulting in convergence on the desired set-point quickly and efficiently.

When operating spray gun system **10** in a flow control operation, controller **14** can identify a fluid flow set-point (i.e., a target flow rate) received via user input or defined by controller **14** (e.g., predefined and stored in computer-readable memory of controller **14**). As shown in FIG. **2**A, fluid flow set-point **38** is provided as input to fluid control loop **34** and is processed by the PID function within fluid control loop **34**. For example, as illustrated in FIG. **2**A, fluid control loop **34** can subtract the measured flow rate received from flow meter **18** from fluid flow set-point **38** to identify a flow rate error (Fe).

Fluid control loop **34** further identifies a mathematical integral of the flow rate error with respect to time (e.g., via numerical integration techniques) and a mathematical derivative of the flow rate error with respect to time (e.g., via numerical differentiation techniques). Fluid control loop **34** multiplies the flow rate error by a proportional gain to produce a scaled proportional error term. Fluid control loop **34** multiplies the integral of the flow rate error by an integral gain to produce a scaled integrated error term. Fluid control loop **34** multiplies the derivative of the flow rate error by a derivative gain to produce a scaled differentiated error term. Fluid control loop **34** determines pressure set-point **40** as the sum of the scaled proportional error term, the scaled integrated error term, and the scaled differentiated error term. Values of the proportional gain, the integral gain, and the derivative gain can be determined experimentally and/or mathematically to achieve target response time and accuracy thresholds.

Fluid control loop **34** outputs pressure set-point **40** for processing by the pressure control loop, as is further described below. Accordingly, fluid control loop **34** identifies a pressure set-point that can be utilized for achieving a fluid flow set-point that is determined and/or received via user input to produce a satisfactory finish on a working surface.

As shown in FIG. **2**B, pressure set-point **40** is provided as input to pressure control loop **36** and is processed by the PID function in pressure control loop **36**. For instance, as was similarly described above with respect to fluid control loop **34** of FIG. **2**A, pressure control loop **36** can implement a PID feedback control loop based on a pressure error representing a difference between pressure set-point **40** and a measured fluid pressure received from pressure sensor **16**. Pressure control loop **36** can determine the pressure error (Pe) by subtracting the measured pressure received from pressure sensor **16** from pressure set-point **40**. Pressure control loop **36** can multiply the pressure error by a proportional gain to produce a scaled proportional error term. Pressure control loop **36** further multiplies the integral of the pressure error by an integral gain to produce a scaled integrated error term, and multiplies the derivative of the pressure error by a derivative gain to produce a scaled differentiated error term. Pressure control loop **36** determines current control value **42** as the sum of the scaled proportional error term, the scaled integrated error term, and the scaled differentiated error term. Values of the proportional gain, the integral gain, and the derivative gain can be determined experimentally and/or mathematically to achieve target response time and accuracy thresholds.

As illustrated in FIG. **2**B, pressure control loop **36** outputs current control value **42** that is utilized for transmitting a control command (e.g., a current control command) to air pilot output **24**. For instance, current control value **42** can represent a current value, such as current value between four and twenty milliamps (or other ranges), which is configured to represent a scale of pressure ranges output by air pilot output **24**. Though the example of FIG. **2**B illustrates and describes current control value **42** as representing an electrical current, it should be understood that other control values can be utilized, such as a voltage control, a digital output, or other control values configured to control operation of air pilot output **24** to supply pressure air.

Air pilot output **24** supplies pressurized air to fluid flow control regulator **22** to increase or decrease fluid pressure within spray gun system **10** based on current control value **42** provided by controller **14**. Increasing or decreasing the fluid pressure within spray gun system **10** results in an increase or decrease in the fluid flow rate exiting spray gun **12**. Pressure sensor **16**, flow meter **18**, and controller **14** (with fluid control loop **34** and pressure control loop **36**) work in conjunction to continuously monitor the pressure and fluid flow rate within spray gun system **10** and also to adjust the fluid pressure within spray gun system **10** to achieve fluid flow set-point **38** (e.g., input by the user into controller **14**). Further, data within pressure control loop **36** can be utilized to indicate precisely when fluid begins to flow within spray gun system **10**, as is discussed further below.

FIG. **3** is a flowchart illustrating example operations of fluid flow detection process **44** within spray gun system **10**. Fluid flow detection process **44** includes steps **100-112**. Step **100** includes receiving pressure set-point **40** from fluid control loop **34**. Step **102** includes receiving the measured fluid pressure within spray gun system **10** from pressure sensor **16**. Step **104** includes calculating pressure error **46** within spray gun system **10**. For instance, controller **14** can subtract the measured pressure received by pressure sensor **16** from pressure set-point **40** to determine pressure error **46**. Step **105** includes performing pressure control loop **36**, as discussed above in FIG. **2**B. For instance, controller **14** can execute pressure control loop **36** to adjust current control value **42** to achieve pressure set-point **40**.

Step **106** includes comparing the calculated pressure error **46** to an error threshold. The error threshold can be a user defined value, an experimental based value, or a mathematically derived value. If pressure error **46** is greater than the error threshold ("YES" branch of Step **106**), a counter is incremented. For instance, controller **14** can increment the counter by an increment value, such as an integer value of two, or other integer or non-integer values. If pressure error **46** is not greater than the error threshold ("NO" branch of Step **106**), the counter is not incremented.

Step **108** includes comparing the counter to a count threshold. The count threshold can be a user defined value, an experimental based value, or a mathematically derived value. If the counter is greater than the count threshold ("YES" branch of Step **108**), this indicates that fluid is flowing within spray gun system **10**. In response to determining that the counter is greater than the count threshold, Step **110** includes controller **14** executing fluid control loop **34** to adjust pressure set-point **40** to achieve fluid flow set-point **38**. If the counter is not greater than the count threshold ("NO" branch of Step **108**), this indicates that fluid is not flowing within spray gun system **10**. In response to determining that the counter is not greater than the count threshold, controller **14** refrains from executing fluid control loop **34** and continues to execute pressure control loop **36** to achieve a predefined pressure set-point.

Step **112** includes decrementing the counter each time pressure error **46** is compared to the error threshold. For example, controller **14** can decrement the counter by a decrement value, such as an integer value of one, or other integer or non-integer value. In some examples, the increment value (i.e., applied in Step **106**) can be greater than the decrement value, such that the counter is incremented at a greater rate than it is decremented, but is incremented only in response to determining that pressure error **46** is greater than the error threshold. Further, controller **14** of spray gun system **10** is configured to set the counter to an initialization value in response to receiving a signal from airflow switch **20** indicating that spray gun **12** is not triggered and airflow is not being distributed from spray gun system **10**. In other words, controller **14** can receive an indication that air is not flowing from airflow switch **20** and in response reset the counter to an initialization value, such as a value or 1.

Fluid flow detection process **44** prevents over-pressurization of spray gun system **10** when the system is in a flow control operation. Fluid flow detection process **44** responds very quickly and directly to fluid flow within spray gun system **10**, even for very low fluid flow rates. Further, fluid flow detection process **44** can replace or eliminate the need for airflow switch **20** because fluid flow detection process **44** indicates precisely when fluid is flowing through spray gun system **10**. Knowing when fluid is flowing helps prevent over-pressurization of spray gun system **10** which results in a stable and even flow exiting spray gun **12**, leading to satisfactory finishes on working surfaces when in flow control operation.

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

The invention claimed is:

1. A spray gun system comprising:
- a spray gun configured to distribute a mixture of air and fluid onto a working surface;
- a pressure sensor fluidly connected to the spray gun, wherein the pressure sensor is configured to measure fluid pressure within the spray gun system; and
- a controller electrically connected to the pressure sensor, wherein the controller is configured to:
  - receive a measured pressure from the pressure sensor;
  - calculate pressure error based on the measured pressure and a pressure set-point;
  - compare the pressure error to an error threshold;

increment an increment counter if the pressure error exceeds the error threshold;

determining that fluid is flowing through the spray gun based on the increment counter exceeding a count threshold;

perform, in response to determining that fluid is flowing through the spray gun based on the increment counter exceeding the count threshold, a flow control loop that adjusts the pressure set-point to achieve a target flow rate; and

perform a pressure control loop to adjust the fluid pressure within the spray gun system to achieve the pressure set-point.

2. The spray gun system of claim **1**, wherein the controller is further configured to refrain from performing the flow control loop in response to determining that the increment counter does not exceed the count threshold.

3. The spray gun system of claim **1**, wherein the controller calculates the pressure error by subtracting the measured pressure from the pressure set-point.

4. The spray gun system of claim **3**, wherein:

the pressure set-point is one of a user defined value, an experimentally-defined value, or a mathematically-derived value based on the target flow rate determined during operation of the flow control loop; and

the error threshold is one of a user defined value, an experimentally-defined value, or a mathematically-derived value.

5. The spray gun system of claim **1**, wherein the controller is further configured to decrement the counter after a comparison of the pressure error and the error threshold, and based on the pressure error being less than the error threshold.

6. The spray gun system of claim **1** and further comprising an airflow switch pneumatically connected to the spray gun and electrically connected to the controller, wherein the airflow switch is configured to send a signal to the controller indicating whether the spray gun is triggered and airflow is being distributed from the spray gun or whether the spray gun is not triggered and airflow is not being distributed from the spray gun.

7. The spray gun system of claim **6**, wherein the controller is further configured to set the counter to an initialization value in response to receiving a signal from the airflow switch indicating that the spray gun is not triggered and airflow is not being distributed from the spray gun system.

8. The spray gun system of claim **1** and further comprising:

a flow meter fluidly connected to the spray gun and electrically connected to the controller;

wherein the flow meter is configured to measure fluid flow rate of the spray gun system; and

wherein the flow meter is configured to send the fluid flow rate measurement to the controller.

9. The spray gun system of claim **8**, wherein the controller is configured to perform the flow control loop to achieve the target flow rate based on a difference between the target flow rate and the fluid flow rate measurement.

10. The spray gun system of claim **1** and further comprising a fluid flow control regulator fluidly connected to the pressure sensor, wherein the fluid flow control regulator is configured to control the fluid pressure within the spray gun system.

11. The spray gun system of claim **10** and further comprising an air pilot output pneumatically connected to the fluid flow control regulator and electrically connected to the controller, wherein the controller is configured to send a signal to the air pilot output to adjust the fluid pressure within the fluid flow control regulator to achieve the pressure set-point.

12. The spray gun system of claim **10** and further comprising a pump fluidly connected to the fluid flow control regulator, wherein the pump is configured to supply fluid to the spray gun system.

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